

# **PALS Radar Signatures of Soil Surfaces and Vegetated Sites in Oklahoma During SGP'99**

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**Abstract**—The Passive/Active L-/S-band (PALS) microwave instrument has been developed by the Jet Propulsion Laboratory (JPL) to investigate the synergism of radiometer and radar measurements for soil moisture remote sensing. In July 1999, PALS was installed on the NCAR C-130 with six successful flights near the Oklahoma City during the Southern Great Plains 1999 (SGP99) Experiment. The data from these and subsequent ocean flights indicate a calibration stability of better than 0.1 dB for each flight. During the SGP99 experiment, there was a significant rain event between the second and the third flights. The data from before and after the rain event indicate a change of 3 to 4 dB in all radar polarization channels, and a decreasing radar backscatter with the drying of surfaces. The dataset enables us to illustrate the correlation of multi-polarization radar signatures with the soil moisture and vegetation bio-mass.

## **INTRODUCTION**

To investigate the synergism of passive and active remote sensing of soil moisture and ocean surface salinity, JPL has developed a Passive/Active L-/S-band microwave instrument (PALS) for acquiring coincidental radiometer and radar signatures of soil and ocean surfaces. The characteristics of the instrument are described in [1,2]. PALS operates at 1.4 and 2.69 GHz for the radiometer channels and 1.2 and 3.1 GHz for the radar channels. The radiometer channels acquire vertically and horizontally polarized emission, and the radar channels perform polarimetric measurements by transmitting vertical or horizontal polarization and receiving these two linearly polarized radar echoes simultaneously. The radar design employs a transmit frequency switching from pulse to pulse to achieve a measurement sensitivity of 0.2 dB for the data averaged over every 0.5 seconds. The calibration of radar transmit power and receiver gain is achieved by an internal calibration loop with a stability of better than 0.1 dB.

The PALS microwave instrument was deployed on the NCAR C-130 with a set of flights during the Southern Great Plain 1999 (SGP99) experiment. There were six flights in the

Little Washita Watershed, Oklahoma from 8-14 July 1999. Many flight lines over selected field sites with a variety of vegetation cover were performed daily, except on July 10 when a storm swept over the Oklahoma.

## **PALS RADAR OBSERVATIONS**

The SGP99 data from the radar channels have been reduced to the normalized radar cross sections ( $\sigma_0$ ) of the surface under investigation, and have been collocated with the in-situ observations of soil moisture and vegetation biomass. Fig. 1 illustrates the radar measurements from both frequency channels versus the volumetric soil moisture for a field covered by weeds with low biomass (bottom panel). The  $\sigma_0$ s from both frequency and all polarization channels increase with increasing soil moisture, apparently due to a change of surface reflectivity.

The ratio of L-band VV and HH radar echoes, which is in the range of 1 to 3 dB, increases with the soil moisture. This agrees with the empirical VV and HH model for bare soil surfaces [3]. While the L-band radar indicates a differing polarization behavior, the S-band VV and HH ratio is near unity and does not have an apparent correlation with the soil moisture. It is probable that the roughness of soil surface is small compared with the L-band a wavelength of 25 cm, but becomes more comparable with the S-band wavelength of about 10 cm. Similar characteristics were observed from other fields with short vegetation cover.

The correlation coefficients ( $\rho$ ) for all polarization combinations are illustrated in the third and fourth panels from the top. The VV and HH correlation is quite high (about 0.7), expected for a soil surface with a low biomass cover. The correlation between co- and cross-polarized returns is small, indicating no-preferred directional surface features.

## **VEGETATION EFFECTS**

There were radar measurements from a corn field with a vegetation water content of about  $7 \text{ kg/m}^2$  (Fig. 2). The L-band radar  $\sigma_0$ s increased with soil moisture, but the S-band failed to indicate a similar sensitivity. It was likely that the corn canopy had significantly attenuated the radar signals and made a dominant scattering contribution at S-band. The volumetric scattering from the corn canopy resulted in a low correlation between the VV and HH radar return signals with a correlation of less than 0.2, which was significantly smaller than that from fields with a low biomass cover. The other expected effects of vegetation cover were an increase of the cross-polarized (VH) radar echoes. The VV and VH ratio was about 6 dB at S-band, considerably smaller than that indicated in Fig. 1 for grass fields, but interestingly the L-band VV and VH ratio was in the range of 10 to 12 dB, similar to what was indicated in Fig. 1. For this particular

case, it does not seem that the ratio of VV and VH L-band echoes is a good indicator of the vegetation biomass. Instead, the VV and HH correlation coefficient appears to be a better indicator.

## SUMMARY

The JPL PALS microwave instrument has acquired a set of coincidental dual-frequency, multi-polarization radar and radiometer observations during the SGP99. The radar observations had been compared with the in-situ measurements of soil moisture and vegetation biomass. The L-band radar  $\sigma_0$ s increase with the soil moisture for the field sites investigated, even for corn fields with a thick canopy. The L-band VV and HH polarization ratios also indicate a dependence on the soil moisture for fields with low biomass, but the S-band signals do

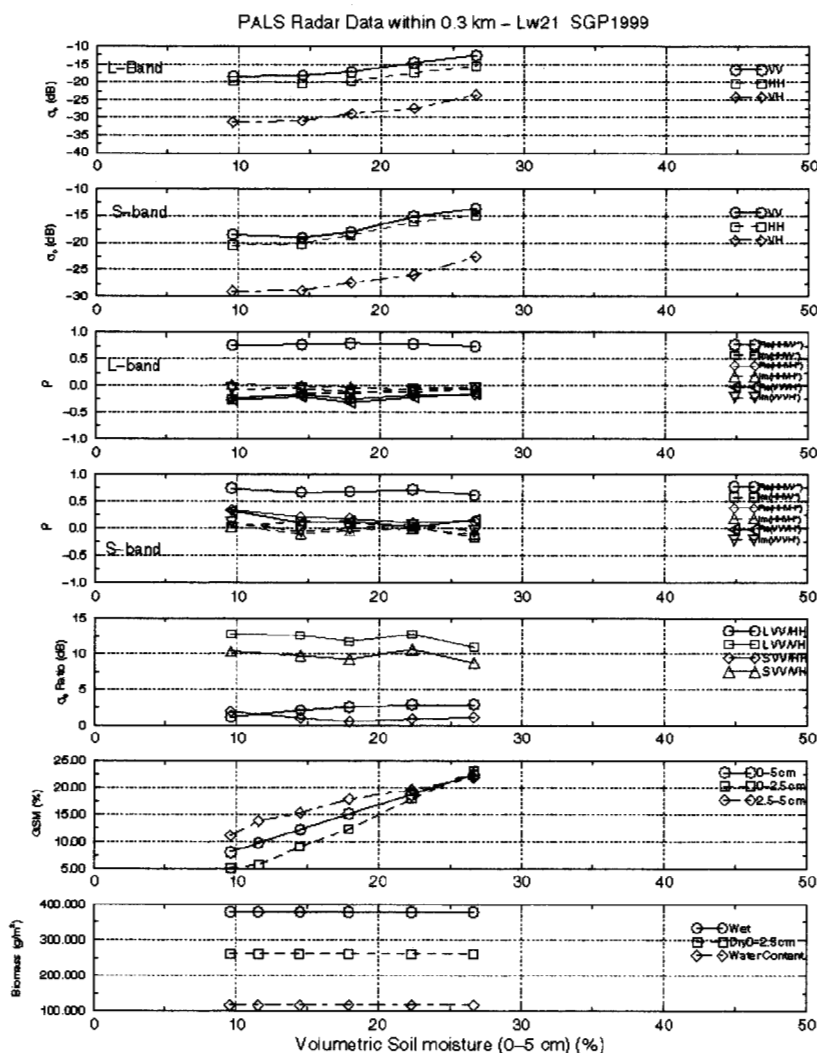


Fig. 1 PALS L- and S-band radar data acquired over a grass field during the SGP99.

not suggest a similar relationship. This suggests that the soil moisture retrieval algorithm suggested in [3] will be applicable to the L-band radar data, but not the S-band data acquired during the SGP99.

Similar to what was indicated in [3], we found that the vegetation cover could have a significant impact on the polarization characteristics of L- and S-band radar scattering. The attenuation and scattering due to the vegetation could reduce the VV and HH polarization ratio, and consequently the soil moisture retrieval algorithm described in [3] will not be applicable for vegetated areas. We also found that the ratio of L-band VV and VH radar echoes alone was probably not a accurate indicator of vegetation cover, but could be augmented by the correlation between VV and HH signals to improve the accuracy of the flag for vegetation cover.

## REFERENCES

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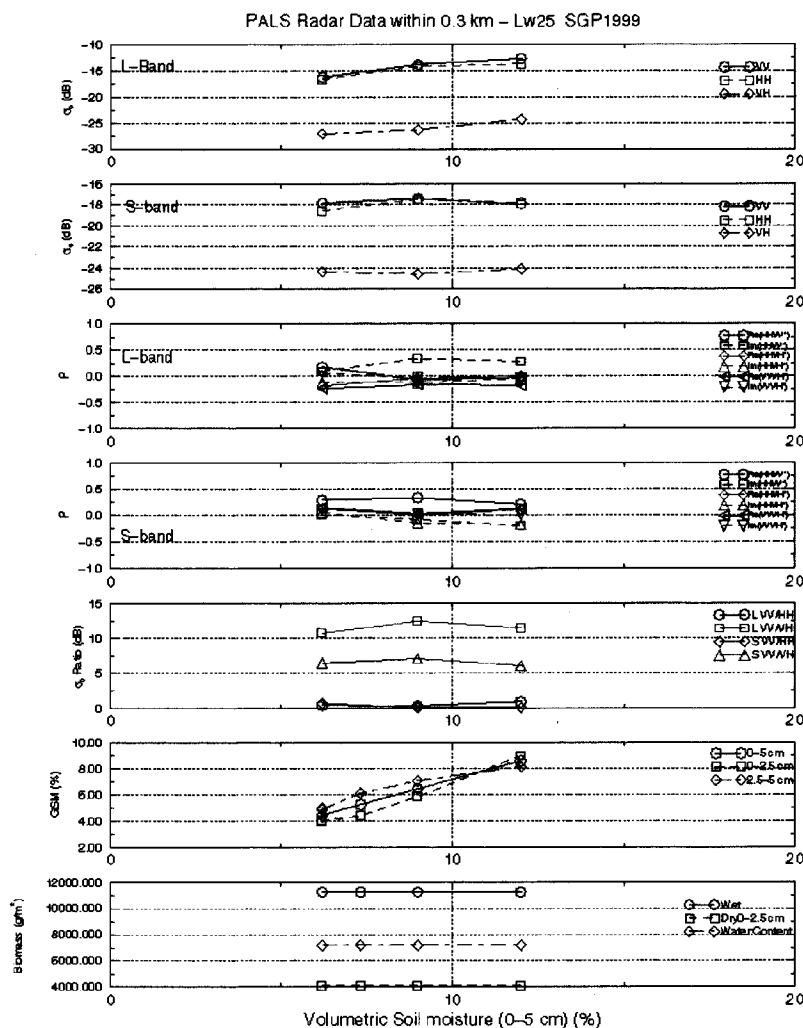


Fig. 2 PALS L- and S-band radar data acquired over a corn field during the